

Claims

We claim:

1. A band-gap voltage reference circuit comprising:

a first and second transistor, each having base, collector and emitter electrodes;

a first resistor network connected to a collector electrode of a first transistor that contains a first resistor that has a high temperature coefficient and a second resistor that has a low temperature coefficient;

a second resistor network connected to a collector electrode of a second transistor;

amplifier means coupled to said pair of transistors to produce an output signal responsive to the difference between the voltages across said pair of resistor networks;

a feedback circuit coupled to said amplifier means and developing a feedback signal corresponding to said output signal;

means to establish different current densities in the separate transistors of said pair of transistors, wherein said current densities vary in response to the ratio of the first and second resistor networks; and wherein said means provides an output voltage that is temperature compensated to a third order.

2. An apparatus as in claim 1, wherein said first resistor network comprises a third resistor connected in parallel to the first resistor

3. An apparatus as in claim 2, wherein a ratio of current densities changes as a function of temperature.

4. An apparatus as in claim 3, wherein the ratio of current densities is greater than unity.

5. An apparatus as in claim 4, wherein said band-gap circuit comprises a third resistor network connected to the emitter electrodes of said transistors.

6. An apparatus as in claim 5, wherein said third resistor network comprises a fifth resistor connected in series with the emitter electrode of said first transistor.

7. An apparatus as in claim 6, wherein said third resistor network comprises a sixth resistor connected in series with the emitter electrode of said second transistor.

8. An apparatus as in claim 7, wherein said second, third, fourth, fifth and sixth resistors have

low temperature coefficients.

9. An apparatus as in claim 8, wherein said band-gap circuit output voltage has a temperature coefficient of less than 0.17 parts per million /degree Celsius.

10. A band-gap voltage reference circuit comprising:

a pair of transistors each having base, collector and emitter electrodes;

an amplifier means having its input coupled to said pair of transistors to produce an output responsive to the difference between the currents through said pair of transistors;

means to produce different current densities in said pair of transistors, wherein a ratio of the current densities is temperature dependent;

an output circuit for said amplifier means and including an output terminal to develop an output voltage;

a first resistor network connected to a collector of a first transistor wherein a first resistor has a high temperature coefficient; wherein the high temperature coefficient of the first resistor compensates for higher order temperature variations of the output voltage.

11. An apparatus as in claim 10, wherein said first resistor network comprises at least two resistors in series with said collector.

12. An apparatus as in claim 11, wherein said first resistor network comprises a resistor with a high temperature coefficient and a resistor with a low temperature coefficient.

13. An apparatus as in claim 12, wherein a second resistor network is connected to the emitters of the transistors.

14. An apparatus as in claim 13, wherein said second resistor network comprises two resistors that have a low temperature coefficient.

15. An apparatus as in claim 14, wherein the first resistor network comprises a resistor with a low temperature coefficient in parallel with a resistor having a high temperature coefficient.

16. A band-gap output voltage reference circuit comprising :

an output circuit for developing an output voltage from a temperature dependent current ratio;
and

a means for limiting the sensitivity of said temperature dependent current ratio.

17. The apparatus as in claim 16, wherein the output circuit includes an operational amplifier.

18. The apparatus as in claim 16, further comprising a means to produce a temperature dependent current ratio which includes a pair of transistors and a first resistor network and a second resistor network.

19. The apparatus as in claim 18, wherein the first resistor network contains a first resistor with a high temperature coefficient and a second resistor with a low temperature coefficient.

20. The apparatus as in claim 19, wherein the first resistor is connected in parallel to the second resistor.

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